RESEARCH ARTICLE

Evaluation of Implant Removal Difficulty in Distal Femur Fractures: A Comparison between Stainless Steel and Titanium Locking Compression Plate

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Abstract

Objectives: Objectives: Titanium plates may offer advantages in fracture healing, yet concerns remain regarding hardware removal due to risks such as screw stripping and cold welding. Whether titanium removal is more difficult than stainless steel remains uncertain. This study compared the ease of implant removal, focusing on distal femur fractures treated with titanium versus stainless-steel plates.

Methods: We conducted a retrospective cohort study of patients with distal femur fractures who underwent implant removal after fixation with either stainless-steel or titanium plates. The primary outcome was difficulty of removal, including cold welding, screw stripping, hardware breakage, and use of advanced tools (screw removal set, trephine, burr). The secondary outcome was operative duration.

Results: Seventy-two patients were included: 31 stainless steel and 41 titanium. Mean in-vivo implant time was 421 ± 498 days for stainless steel and 360 ± 409 days for titanium (P = 0.57). Difficulties with removal occurred in 13% of stainless-steel cases and 12% of titanium cases (P = 0.92). Screw removal sets were required in 9.7% and 9.8% of patients, respectively (P = 0.99). Advanced extraction tools were used in 3 patients per group (P = 0.72). Cold-welded or stripped screws occurred in 2 patients in each group (P = 0.77). Mean operative time was 155 ± 80 minutes for stainless steel versus 118 ± 67 minutes for titanium (P = 0.06).

Conclusion: In distal femur fractures, titanium plate removal is not associated with increased technical difficulty compared with stainless steel implants.

Level of evidence: III

Keywords: Distal femur, Hardware removal, Locking compression plate, Stainless steel, Titanium

Introduction

The history of fracture fixation using metal plates dates back to the 19th century.[1] Since that time, significant advancements in metallurgy and fixation techniques have been made to address challenges such as corrosion and inadequate material strength.[2,3] These developments have culminated in the emergence of modern implants, with stainless steel and titanium plates being the most prevalent materials utilized in clinical practice.[4]

Locking compression plates are increasingly employed in the treatment of distal femur fractures, with both stainless steel and titanium plates utilized for this purpose.[5-7] Titanium plates offer a modulus of elasticity that closely resembles that of bone, rendering them less rigid and more capable of withstanding repeated loads;[4] In contrast, increased stiffness of electropolished stainless steel might impede fracture healing in certain anatomical locations, particularly in the distal femur.[4,8]

Despite the advantages of titanium plates in promoting superior fracture healing, some orthopedic surgeons express hesitation in their use due to concerns about the challenges associated with future hardware removal.[9]

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Factors, such as cold welding and screw stripping, contribute to this apprehension.[9-11] Cold welding refers to the adhesion of metal surfaces due to the lack of an oxide layer and the application of pressure [Figure 1]. Titanium's tendency to form a passivation layer and its strong oxygen affinity makes it more susceptible to this issue, especially when screws are tightly secured. In contrast, stainless steel is less reactive and thus less likely to experience cold welding.[4,12] From a biomechanical standpoint, titanium's lower stiffness, which more closely matches cortical bone, may promote bone healing. Stainless steel, being stiffer, can provide stronger initial fixation but may impede callus formation in some cases.[4,12]

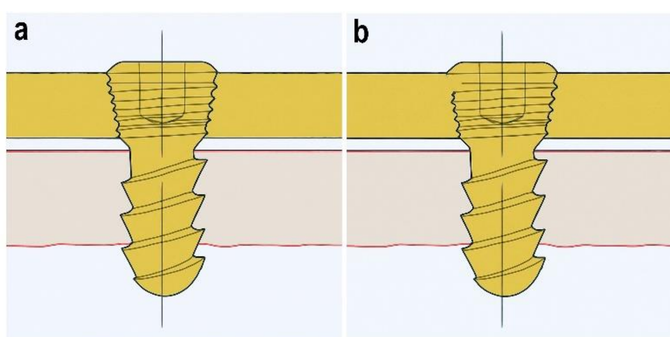

Figure 1. Illustration of a locking screw engaged in a locking plate. The left image (a) shows normal engagement without cold welding, where a clear interface is visible between the screw head and the plate. The right image (b) demonstrates cold welding at the screw-plate interface, where the metallic surfaces have merged due to high contact pressure and the absence of surface oxide layers, resulting in a loss of distinct boundaries caused by solid-state adhesion between the two metals

Although prior studies have documented the difficulties associated with removing first-generation locking titanium plates, resulting in increased operating room time and costs,[9,13] the overall body of literature on this topic remains limited. Consequently, there is no consensus regarding whether the removal of titanium plates is more challenging than that of stainless-steel plates/screw constructs.

A recent study investigating difficulties with titanium implant removal revealed that the removal of titanium implants from the lower extremity, particularly in the distal femur, was more challenging than other areas in the body.[9] Therefore, in this study, we aimed to specifically compare the difficulty of removing stainless steel and titanium implants used for distal femur fracture fixation. The primary outcome is to assess the difficulty of implant removal, specifically evaluating the incidence of stripped screws, cold-welded screws, and the necessity for specialized tools during the surgical procedure.

Materials and Methods

Study Design

This study was conducted using data from a large health system and received approval from the research ethics board at our institution. We retrospectively reviewed the medical charts for patients who sustained distal femur fractures treated with lateral locking plates and subsequently underwent hardware removal between January 2015 and December 2020. Patients with known pathologic fractures, metabolic bone diseases, or those under 18 years of age at the time of surgery were excluded from the study. Seventy-two patients met the study criteria and were included in the analysis, with 31 stainless steel plates and 41 titanium plates. The study flow diagram is demonstrated in [Figure 2].

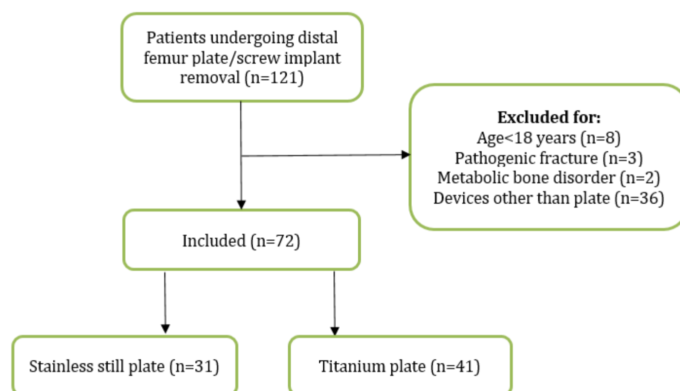

Figure 2. Flow diagram of the study

Data Collection and Outcomes of Interest

Patient data was collected from electronic medical records and included demographics, comorbidities, fracture and implant characteristics, operative records, and radiographic data. The Primary outcome assessed in this study was difficulty with implant removal. Difficult implant removal was defined as the presence of implant cold-welding, screw stripping, intraoperative hardware breakage, or the need for advanced tools (screw removal set, trephine, metal cutting burr). A combined measure of difficulty with hardware removal was assessed if one or more of the mentioned variables were documented. The secondary outcome of the study was operation time.

Statistical Analysis

Statistical analysis was conducted using SPSS for Windows, version 28. Descriptive data were presented as mean ± standard deviation for numerical variables and as counts with percentages for categorical variables. Comparisons of mean values between the two groups were performed using either an independent t-test or the Mann–Whitney U test, as appropriate. Chi-square tests or Fisher's exact tests were employed to compare categorical variables. A P-value of less than 0.05 was considered statistically significant.

Results

Baseline characteristics

The study population included 22 (31%) males and 50 (70.0%) females with a mean age of 64 ± 16 years (range 48-79). The most common type of fracture was intra-articular (n=29, 41%), followed by supracondylar fracture (n=13,

18%).

There was no significant difference in plate length, measured by the number of holes, between the two groups (P = 0.67). Similarly, the number of screws used for plate fixation showed no significant difference (P = 0.69). In both groups, non-union was the most prevalent cause of plate removal. The mean implant in-vivo time was 421 ± 498 days for the stainless-steel group and 360 ± 409 days for the titanium group (P = 0.57). Additionally, no other significant differences were observed in the baseline characteristics of the two groups [Table 1].

Table 1. Comparison of baseline characteristics between the steel and titanium plate group

Variable	Steel plate (n=31)	Titanium plate (n=41)	P-value
Age at hardware removal (mean, sd)	64.1±13	63.9±16	0.96
BMI (mean, sd)	31.5±6.9	30.6±6.6	0.44
Sex			
• *Male*	11 (35)	11 (27)	0.45
• *Female*	20 (65)	30 (73)	
Current smoker (n, %)	8 (26)	10 (24)	0.93
Diabetes (n, %)	13 (42)	10 (24)	0.13
End-Stage Renal Disease (n, %)	1 (3)	1 (2)	0.97
Osteoporosis (n, %)	18 (58)	29 (68)	0.21
Fracture type			
• *Intra-Articular*	11 (35)	18 (44)	
• *Supracondylar*	6 (19)	7 (17)	
• *Distal shaft*	1 (3)	3 (7)	0.84
• *Peri-Prosthetic TKA*	12 (39)	12 (29)	
• *Peri-Prosthetic IMN*	1 (3)	1 (2)	
Number of plate holes (n, %)	11.74 ± 3.13	11.38 ± 3.79	0.67
Number of screws (n, %)	10± 2	10± 3	0.69
Reason for plate removal			
• *Local Irritation*	5 (16.1)	9 (21.9)	
• *Malunion*	4 (12.9)	2 (4.9)	
• *Non-union*	11 (35.5)	12 (29.2)	
• *Peri-prosthetic fracture*	0	4 (9.8)	0.34
• *Infection*	5 (16.1)	8 (19.5)	
• *Conversion to arthroplasty*	1 (3.2)	2 (4.9)	
• *Failed fixation*	5 (16.1)	4 (9.8)	
Days to plate removal (mean, sd)	421± 498	360±409	0.57

TKA: total knee arthroplasty; IMN: intramedullary nail.

Hardware removal difficulty

In total, four patients (13%) in the steel plate group and five patients (12%) in the titanium plate group experienced difficulties with plate removal (P = 0.92). The broken screw removal set was utilized in 3 patients (9.7%) from the steel plate group and four patients (9.8%) from the titanium plate group (P = 0.99). Cold-welded or stripped screws were reported in 2 patients from each group (P = 0.77). Advanced extraction tools were employed in 3 patients from each group (P = 0.72). In the stainless-steel group, advanced extraction tools included the Trephine (used twice) and a metal cutting burr (once). In the titanium group, advanced extraction tools included a carbide drill tip (once), a metal cutting burr (once), and a Trephine (once).

In the stainless-steel group, the mean implant in-vivo time was 416 ± 518 days for patients without difficult removal and

454 ± 393 days for patients with difficult removal (P = 0.88). In the titanium group, the mean implant in-vivo time was 336 ± 413 days for patients without difficult removal and 532 ± 363 days for patients with difficult removal (P = 0.32).

The mean operative time was 154.5 ± 80. minutes for the steel plate group and 118 ± 67 minutes for the titanium plate group; this difference was not statistically significant (P=0.06) [Table 2].

Table 2. Comparison of hardware removal difficulty and operation time between the two groups

Variable	Stainless Steel (n=31)	Titanium (n=41)	P-value
Difficult removal (n, %)	4 (12.9)	5 (12.2)	0.57
Broken screw removal set utilized (n, %)	3 (9.7)	4 (9.8)	0.99
Advanced extraction tools used (n, %)	3 (9.7)	3 (7.3)	0.72
Cold-Welded or stripped screws (n, %)	2 (6.4)	2 (4.9)	0.77
Operation time in minutes (mean, sd)	154.5±79.6	117.7±66.7	0.06

sd - standard deviation

Discussion

In this study, we compared the difficulty of plate and screw removal in patients with distal femur fractures who were treated with either stainless steel or titanium implants. Approximately 12% of cases experienced difficulty with implant removal, a rate similar between the two groups (13% for stainless steel and 12% for titanium). Moreover, the use of broken screw removal sets and advanced extraction tools, as well as the rates of cold-welded or stripped screws, showed no significant differences between the two groups. Additionally, operation times were similar between the two groups.

The difficulty of plate/screw implant removal following fracture fixation has been discussed in a limited number of earlier studies. In a retrospective study, Dehghan et al.[9] investigated the challenges associated with removing titanium plates and screws. Out of 1,274 screws removed, 14 (1.1%) were stripped, 8 (0.6%) were cold-welded, 42 (3.3%) were loose, 13 (1.0%) were broken, and 8.2% of plates had bone overgrowth. Complications arose in 7.6% of the procedures, necessitating the use of advanced tools. The study found that complicated implant removals were linked to longer implant durations, younger patient age, and a higher incidence of lower extremity surgeries, especially those involving the distal femur, resulting in significantly longer operation times. The study also reported that compared to other screw sizes, 5.0mm locking screws had the highest rates of cold welding (7.7%) and stripping (12%). Since 5.0mm screws are typically used in distal femoral locking plates, these implants had a higher rate of difficulty with implant removal. However, one of the criticisms of this study was the lack of a stainless-steel control group. The study results showed that the complications requiring the use of advanced tools for implant removal occurred in 12% of patients in the titanium group and 13% in the stainless steel group, which is similar to the results of Dehghan et al.'s study on distal femur plate removals.

Other studies have also reported difficulties with the removal of distal femur implants. Concerns with titanium screw removal stem from various reports in the early 2000s, which documented difficulties with removing distal femur Less Invasive Stabilization System (LISS) plates, particularly due to screw slippage or cold welding.[14-16] Suzuki et al.[14] reported difficulties with the removal of 36 LISS plates. The authors reported that 39% of screws were associated with difficulty in removal, and 11% required specialized instruments for removal due to cold welding or screw strippage. However, again, a stainless-steel control group was lacking. In this study, the results showed that stripped or cold-welded screws occurred in only 4.9% of patients in the titanium group and 6.4% of patients in the stainless-steel group. Also, the usage of specialized instruments for implant removal was 7.3% in the titanium group and 9.7% in the stainless-steel group. This difference may be due to changes in plate and screw design.

Regarding comparative studies assessing the ease of titanium and stainless steel implants, there is limited data. A comparative study of titanium versus stainless steel implant removal was conducted by Bachoura et al.[17] The authors reported that problematic implant removal from the elbow occurred if the implant was left in place for more than 12 months, particularly with titanium alloy implants. However, no significant difference was observed between steel and titanium implants if extracted earlier than 12 months. This study found no difference in the difficulty of implant removal between stainless steel and titanium implants. The mean in vivo time for implants in this study was approximately 12 months, which is consistent with the results of this study.

Unlike previous studies, our case series found no significant difference in the difficulty of implant removal between stainless steel and titanium plates. This difference may be attributed to the relatively short duration of time that the titanium plates were kept in situ in the present study (on average, 360 days). However, other factors, such as patient characteristics and implant features, could also play a role. Therefore, further investigations are needed to better understand the challenges associated with titanium plate removal in patients with distal femur fractures.

The observed 12% rate of implant removal difficulty is

higher than that reported in some previous studies. Several factors may account for this discrepancy, including the relatively long duration of implant retention, the frequent use of 5.0 mm locking screws in distal femur fixation, and the inclusion of complex intra-articular fractures, which are inherently more challenging to manage. Additionally, variability in surgical techniques, institutional protocols, and indications for implant removal may have contributed to the elevated rate of complications. Further research is warranted to clarify the underlying causes of this higher incidence.

Overall, the results of the present study suggest that the extraction of titanium distal femoral locking plates may not be more challenging than stainless steel implants. However, the study does have limitations. The primary limitation is its retrospective design, which introduces the potential for various biases in information. Variability in patient characteristics, surgeon preferences, and implant manufacturers could have influenced outcomes. While such heterogeneity is inherent in retrospective orthopedic studies, its impact was partly mitigated by selecting patients treated at a single health system over a defined period. Moreover, the use of electronic medical records helped mitigate potential inaccuracies.

Furthermore, by comparing two material types within the same institution and timeframe, we aimed to minimize variability in patient selection and surgical approach. Additionally, the study only assessed distal femoral locking plates, which may not be generalizable to other anatomic locations or plate and screw sizes. However, this narrow focus provides a homogeneous patient population, allowing for a more consistent analysis of factors influencing implant removal difficulty. Also, the small patient sample size restricted the ability to conduct multivariable analyses. The relatively small sample size may have underpowered the study to detect subtle differences between groups. However, hardware removal in distal femur fractures remains a niche indication, particularly when stratified by implant type, which limits the available sample size. Therefore, prospective studies with larger cohorts are warranted to validate the findings presented here.

Conclusion

Removal of titanium plate/screw implants in the distal femur does not lead to increased difficulty compared to stainless steel implants. Although the biomechanical properties of titanium could theoretically increase the likelihood of difficulties screw cold welding and stripping, these were found to be similar between stainless steel and titanium implants. Other factors, such as the duration of implantation, may contribute more to these challenges. Further investigations are needed to identify and clarify the risk factors associated with challenges in implant removal.

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Declaration of Informed Consent: There is no information (names, initials, hospital identification numbers, or photographs) in the submitted manuscript that can be used to identify patients.

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